Desalination & Water Management
Opportunities & Issues

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Over one billion people in the world lack access to safe drinking water. By 2025, over 3.5 billion people will live in areas facing severe water shortage. Problem is increasing day by day.
## Global Desalination Scenario

<table>
<thead>
<tr>
<th>Year</th>
<th>Global cumulative contracted desalting capacity (Million Litre per Day)</th>
<th>Global cumulative online desalting capacity (Million Litre per Day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>7000</td>
<td>5000</td>
</tr>
<tr>
<td>1990</td>
<td>15000</td>
<td>14000</td>
</tr>
<tr>
<td>2000</td>
<td>30000</td>
<td>26000</td>
</tr>
<tr>
<td>2010</td>
<td>74000</td>
<td>63000</td>
</tr>
<tr>
<td>2016</td>
<td>95000</td>
<td>88000</td>
</tr>
</tbody>
</table>

Source: IDA Desalination Yearbook 2016-2017
Nuclear Desalination

Why Nuclear Desalination?
## Nuclear Desalination: A Low Carbon Desalination Fuel

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Coal</th>
<th>Oil</th>
<th>Natural gas</th>
<th>Nuclear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grams of emitted CO₂/m³ permeate (4KWH/m³ RO Desalination Plant)</td>
<td>3600</td>
<td>2479.5</td>
<td>1479.8</td>
<td>11.8</td>
</tr>
<tr>
<td>Reactor type</td>
<td>Location</td>
<td>Desalination Technology</td>
<td>Capacities (MLD)</td>
<td>Status</td>
</tr>
<tr>
<td>-------------</td>
<td>---------------------</td>
<td>-------------------------</td>
<td>------------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>LMFR</td>
<td>Kazakhstan (Aktau)</td>
<td>VTE-MED</td>
<td>80 (Design: 145)</td>
<td>Commissioned in 1973 and operated till 1999</td>
</tr>
<tr>
<td>PWR</td>
<td>Japan (Ohi, Takahama, Ikata, Genkai)</td>
<td>MSF, MED, RO</td>
<td>1–2</td>
<td>In service; operating experience &gt;125 reactor years</td>
</tr>
<tr>
<td>PHWR</td>
<td>India (Kalpakkam)</td>
<td>Hybrid (MSF-RO)</td>
<td>6.3 (4.5 MLD MSF+ 1.8 MLD RO)</td>
<td>Operating and in service since 2002 and 2008</td>
</tr>
<tr>
<td>PHWR</td>
<td>Pakistan (KANUPP)</td>
<td>MED</td>
<td>1.6</td>
<td>Commissioned in 2009</td>
</tr>
</tbody>
</table>
## Nuclear Desalination Activities

<table>
<thead>
<tr>
<th>Reactor type</th>
<th>Location</th>
<th>Desalination Process</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>PWR</td>
<td>Rep. of Korea, Argentina, etc.</td>
<td>MED RO</td>
<td>Integral SMRs (design stage)</td>
</tr>
<tr>
<td>PWR</td>
<td>Russia</td>
<td>MED RO</td>
<td>Floating unit (design stage)</td>
</tr>
<tr>
<td>NHR-200</td>
<td>China</td>
<td>MED</td>
<td>Dedicated heat only integral PWR (design stage)</td>
</tr>
<tr>
<td>HTRs</td>
<td>France, The Netherlands, South Africa</td>
<td>MED RO</td>
<td>Multipurpose reactor, GT-MHR and PBMR; under development and design</td>
</tr>
</tbody>
</table>
Nuclear Desalination Plants

Nuclear Desalination Plant coupled with LMFR in Aktau, Kazakhstan

Nuclear Desalination Plant coupled with PWR in Ohi, Japan

Nuclear Desalination Plant coupled with PHWR in KANUPP, Pakistan
Nuclear Desalination involves three technologies: (1) Nuclear; (2) Desalination; (3) Coupling.

**Nuclear Reactor**

- All nuclear reactor types can provide the energy required by the desalination processes.
- Small and Medium Reactors (SMRs) are good for small grids or remote areas or small production.
- Big reactors are excellent for cogeneration especially if waste heat is re-used.
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Thermal Desalination</th>
<th>Membrane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principle</td>
<td>Flashing</td>
<td>Boiling</td>
</tr>
<tr>
<td>Operating temperature (°C)</td>
<td>105-120</td>
<td>60-70</td>
</tr>
<tr>
<td>Type of energy requirement</td>
<td>Thermal</td>
<td>Thermal</td>
</tr>
<tr>
<td>Energy requirement</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Desalinated Product water quality (ppm TDS)</td>
<td>1-2 (Distilled)</td>
<td>1-2 (Distilled)</td>
</tr>
<tr>
<td>Technology vulnerability to feed quality</td>
<td>Robust</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Susceptible</td>
</tr>
</tbody>
</table>
Advantages:

- Two qualities of product water: (i) distilled water for high end applications; (ii) Better quality potable water through blending.
- Better redundancy
- Higher temperature feed water to RO system for better performance.
- Longer membrane life
Water Consumption in NPPs & Need for Nuclear Desalination

NPPs require water during:

1. **Construction (4 to 5 years):** 400,000-800,000 cubic metre water requirement for excavation, concrete mixing, construction staff.

2. **Commissioning and operation:** Different qualities of water for condenser cooling, component cooling, service water systems, Process water requirement (make-up water), Ultimate heat sink (safety)

3. **Shut-down & 4. Decommissioning**
Water Consumption in NPPs & Need for Nuclear Desalination (contd.)

Distribution of water consumption for different uses in a 1000 MW(e) plant

- Component Cooling Water Makeup: 3%
- Condensate Polishing Plant: 11%
- Waste Treatment: 16%
- Sanitary and Potable: 26%
- Fire Protection: 3%
- Primary Make-up: 1%
- Secondary Makeup: 40%

Turbine Condenser Cooling and Service Cooling Water Flow-rates used in Closed Loop for a 1000 MW(e) NPP

<table>
<thead>
<tr>
<th></th>
<th>Turbine condenser cooling (m³/s)</th>
<th>Supporting systems cooling (m³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recirculating cooling water</td>
<td>46</td>
<td>1.2</td>
</tr>
<tr>
<td>Evaporation losses</td>
<td>0.63</td>
<td>0.016</td>
</tr>
<tr>
<td>Blow-down losses</td>
<td>0.4</td>
<td>0.011</td>
</tr>
<tr>
<td>Make up water to compensate losses</td>
<td>1.03</td>
<td>0.027</td>
</tr>
</tbody>
</table>
Water Consumption in NPPs & Need for Nuclear Desalination (contd.)

Need for Quality Water ➡️ Marriage between Nuclear & Desalination

1. For requirement during Construction (Potable water by RO)
2. During Operation (Hybrid: Potable water by RO for onsite use and Distilled water by MED/ MSF for NPP makeup DM water)
3. In emergency/ accident (Potable water by RO for decontamination)
4. This also has the benefits of sharing of resources between NPP and Desalination Plant; such as:
   1. Seawater intake,
   2. Outfall,
   3. better environmental impact. etc
Case Study (India)
Madras Atomic Power Station in South-East Coast of India
Nuclear Desalination Plant at Kalpakkam (India)

• Nuclear: PHWR based power station providing low pressure steam, electricity and sea water.

• Desalination: Uses Hybrid Technology (Total capacity: 6.3 MLD)
  • MSF: 4.5 MLD capacity
  • RO: 1.8 MLD capacity

• Coupling system: Isolation loop.

• This is the largest operating nuclear desalination plant based on hybrid technology.
Hybrid MSF-RO: An Innovation with Societal Application in Kalpakkam (India)

Hybrid MSF-RO Sea Water Desalination Plant (6.3 MLD capacity)

MSF (Distilled quality product water)

UF Pretreatment

RO (Potable quality product water)
Retrofitting of Nuclear Desalination System to Operating NPP

**Important Considerations:**
1. Transients: Load variation of steam consumption
2. Coupling Design for safe operation
3. Monitoring the activity level in isolation loop and desalination system
4. Fulfils the make-up water requirement and augments potable water requirement in the area.

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Retrofitting of MSF Nuclear Desalination Plant to Operating MAPS at Kalpakkam India
Low Temperature Evaporation based Desalination Plant (30 KLD capacity) using Waste Heat of Nuclear Reactor in Trombay (India) for Seawater Desalination

Key Features:

i. Energy input: Waste heat as hot water;
ii. No chemical requirement,
iii. Product quality: DM water
Innovative Water Management
Efficient management of water in nuclear facilities is important. It requires different qualities of water such as demineralised quality of water to sea water.

Sea Water as Condenser Coolant for coastal Nuclear Reactor/ Power Station

Sea Water for Desalination

Distilled quality Water for High End Use

Potable Quality Water for Drinking and other purposes

Process/ Utilities

Water Recycle & Reuse
Innovative Water Management

CONVENTIONAL WATER TREATMENT

Raw Water → Water Treatment Plant → Treated Water → Process → Effluent → Effluent Treatment Plant → Discharge

INNOVATIVE WATER MANAGEMENT USING MEMBRANE PROCESSES

Source Reduction → Water Treatment Plant → Treated Water → Process → Effluent or waste water → Product Recovery Plant (NF) → Recovered Product → Partially treated effluent or waste water

Recovered Product → Water Recovery & Recycle Plant (RO) → Recycled Water → Reuse elsewhere → Minimal Discharge

Reduce/ Recover/ Recycle

Water Reuse

Product Recovery

Waste Minimisation

Opportunities/ Issues/ Recommendations
1. Interest in using nuclear energy for producing desalinated water as well as innovative water management in nuclear establishment is growing.

2. The use of nuclear reactors for seawater desalination has already been demonstrated in several countries with operational experience of over 200 reactor-years.

3. The cogeneration of electricity and useful heat for desalination is advantageous due to sharing of infrastructural facilities, better thermodynamic efficiency and economic optimization.
4. Both nuclear power and desalination technologies are matured technologies.

5. Nuclear desalination offers significant potential to substitute fossil fuel as a source of energy for desalination to deal with adverse impact of climate change on water resources.

6. There would be need for small, medium and large size nuclear desalination plants in the coastal areas.
Issues

1. For nuclear desalination to be attractive in any given country, two factors need to be in place simultaneously: i) lack of water and ii) the ability to use nuclear energy for desalination. *Countries in need of water, at times, do not have the infrastructure for nuclear power.*

2. Public acceptance

3. A greater understanding of requirements and responsibilities among vendors and users of nuclear desalination technologies i.e. nuclear power and desalination technologies.
Recommendations

1. Training in developing countries, such as training workshops, technical meetings

2. Sharing information

3. Promoting research, development and innovations such as collaborative research activities

4. Proper understanding of requirements and responsibilities among vendors and users of nuclear desalination projects
Recommendations (contd.)

R&D Efforts Required

1. Reduce the energy requirement through technological innovations,
2. Coupling aspects for different types of reactors and desalination systems,
3. Micro, small & medium Size reactors,
4. Low grade and waste heat utilization,
5. Hybrid technologies,
6. Recovery of valuables from brine and waste water.
Thanks